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TECHNICAL NOTE

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EXPERIMENTAL INVESTIGATION AT A MACH NUMBER OF 3.11 OF THE LIFT, DRAG, AND PITCHING-MOMENT CHARACTERISTICS OF FIVE BLUNT LIFTING BODIES

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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SUMMARY

Five lifting reentry shapes were tested to determine the lift, drag, and pitching-moment characteristics at a Mach number of 3.11 and a Reynolds number of 16×10^6 per foot.

As was expected, the results of the tests show that all the bodies were statically unstable about the geometric center of the bodies, except one which was neutrally stable. The results indicated that Newtonian theory might be applied for estimating the drag at zero angle of attack and the pitching-moment-curve slope. Indications are, however, that Newtonian considerations would not apply for estimating the normal force of bodies of the type tested at the Mach number of the tests.

INTRODUCTION

An analytical study of the behavior of flattened disk bodies, of relatively high lift capability, that travel edgewise and are stabilized by spin about an axis normal to the direction of flight is presented in reference 1. The purpose of the investigation of reference 1 was to study the use of such spinning disk bodies for reentry applications. The aerodynamic characteristics required for the calculations of the dynamic behavior of the configurations were determined from Newtonian considerations since suitable experimental data were lacking.

The purpose of the present paper, therefore, is to provide experimental data, at zero spin, of the lift, drag, and pitching moment of five blunt disk bodies at a Mach number of 3.11 which could be useful in an analysis such as that presented in reference 1. The characteristics of a number of blunt, axisymmetric, nonlifting bodies are presented in references 2, 3, and 4.

SYMBOLS

The data are referred to the stability system of axes (fig. 1) and are presented in the form of standard coefficients of force and moments about the geometric center of the models. The coefficients and symbols used herein are defined as follows:

C_D	drag coefficient, $\frac{\text{Drag}}{qS}$
C_L	lift coefficient, $\frac{\text{Lift}}{qS}$
C_N	normal-force coefficient, $\frac{\text{Normal force}}{qS}$
C_m	pitching-moment coefficient, $\frac{\text{Pitching moment}}{qSd}$
C_{L_α}	slope of curve of lift coefficient with angle of attack, per deg
C_{m_α}	slope of curve of pitching-moment coefficient with angle of attack, per deg
d	diameter of model, ft
M	Mach number
p	static pressure, lb/sq ft
q	dynamic pressure, $\frac{\gamma}{2} pM^2$, lb/sq ft
S	reference area of models, $\frac{\pi d^2}{4}$, sq ft
α	angle of attack, deg
γ	ratio of specific heat at constant pressure to specific heat at constant volume

APPARATUS AND TESTS

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The tests were conducted at the Langley gas dynamics laboratory in a blowdown jet having a rectangular test section approximately 12 inches square. The nozzle operates at an average Mach number of 3.11. The tests were made at a settling-chamber stagnation temperature of 100° F and a stagnation pressure of 100 pounds per square inch gage or 114.7 pounds per square inch absolute. The Reynolds number was approximately 16×10^6 per foot. For models 1 to 4, the Reynolds number was approximately 3.3×10^6 based on the model diameter of 2.5 inches. The Reynolds number for model 5 was about 4.2×10^6 based on the model diameter of 3.125 inches.

Tests were made through an angle-of-attack range from about -4° to about 22° for models 1 to 4 and from about -3° to about 14° for model 5 because of balance limitations. For each angle of attack, measurements were made of the normal force, axial force, and pitching moment by means of an electrical strain-gage balance. All models were made of Duralumin, and are shown in the photograph given in figure 2. The geometric characteristics of the models are given in figure 3. All models were mounted on an external strain-gage balance, which was in turn mounted on a sting.

RESULTS AND DISCUSSION

The results of the investigation are presented in figures 4 to 7. The pitching moments are presented about the geometric center of each model. The normal and axial forces measured were converted to lift and drag coefficients.

The lift, drag, and pitching-moment characteristics of model 1 are compared with those of model 2 in figure 4. Model 2, which is the same as model 1 except for the rounded corners, has a higher slope of the curve of lift and pitching-moment coefficients with angle of attack than model 1 and, also, has approximately 10 percent lower drag coefficient. The zero slope of the curve of pitching-moment coefficient with angle of attack for model 1 would be expected on the basis of Newtonian calculations since model 1 is effectively a flat plate under Newtonian considerations. The value of the drag coefficient, 0.85, calculated for model 1 at zero angle of attack compares favorably with the measured value of 0.77. However, the values (not presented in the present paper) of normal-force coefficient, calculated by Newtonian methods

$\left(C_N = 2 \sin^2\alpha\right)$, are considerably less than those measured throughout the angle-of-attack range. Calculations of normal-force coefficient for a number of blunt, axisymmetric bodies reported on in reference 2, however, showed extremely good agreement with values measured at a Mach number of 3.11. It is likely that better agreement between measured and calculated values of normal force for model 1 would be obtained for tests at Mach numbers appreciably greater than 3. Although no calculations were made for models 2 to 5, it is believed that similar results would be obtained.

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In figure 5 is shown a comparison of the lift, drag, and pitching-moment characteristics of models 3 and 5. Model 5 has a higher lift-curve slope, a lower drag, and about the same pitching-moment-curve slope as model 3.

Figure 6 shows a comparison of the lift, drag, and pitching-moment coefficients of models 4 and 5. The models are both of elliptic cross section but of different thickness ratio. Model 5, which has the smaller thickness ratio (ratio of maximum thickness to diameter), has a higher lift-curve slope than model 4. For the moment-center location of the present investigation, model 5 is more unstable in the low angle-of-attack range than any of the models tested. The following table summarizes the aerodynamic characteristics of the models tested:

Model	C_{L_α}, per deg	C_D at zero α	C_{m_α}, per deg
1	0.0042	0.77	0.0000
2	.0065	.68	.0011
3	.0088	.48	.0030
4	.0097	.40	.0022
5	.0120	.30	.0032

From the table it can be seen that all the bodies were statically unstable about the geometric center of the bodies, except model 1 which was neutrally stable.

The ratio of lift coefficient to drag coefficient C_L/C_D, plotted against angle of attack is presented in figure 7 for each of the models. Although the maximum C_L/C_D ratios were not obtained because of balance limitations, the values presented may be useful for purposes of comparison.

CONCLUDING REMARKS

As was expected, the results of an investigation conducted at a Mach number of 3.11 and a Reynolds number of 16×10^6 per foot to determine the aerodynamic characteristics of five lifting shapes indicated that all the bodies were statically unstable about the geometric center of the bodies, except one which was neutrally stable. The results indicated that Newtonian theory might be applied for estimating the drag at zero angle of attack and the pitching-moment-curve slope. Indications are, however, that Newtonian considerations would not apply for estimating the normal force of bodies of the type tested at the Mach number of the tests.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., August 19, 1959.

REFERENCES

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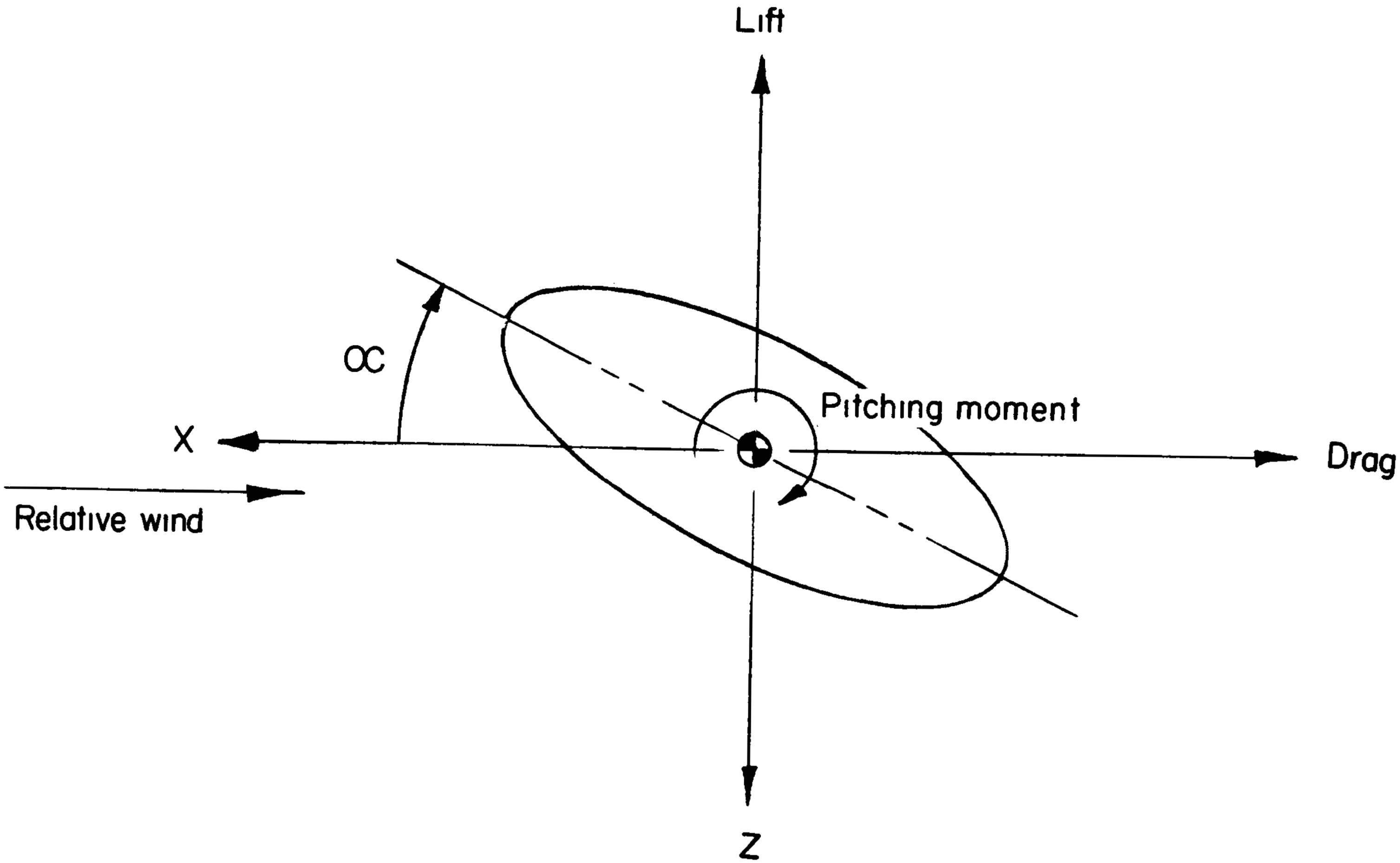

Figure 1.- Stability system of axes. Arrows show positive directions.

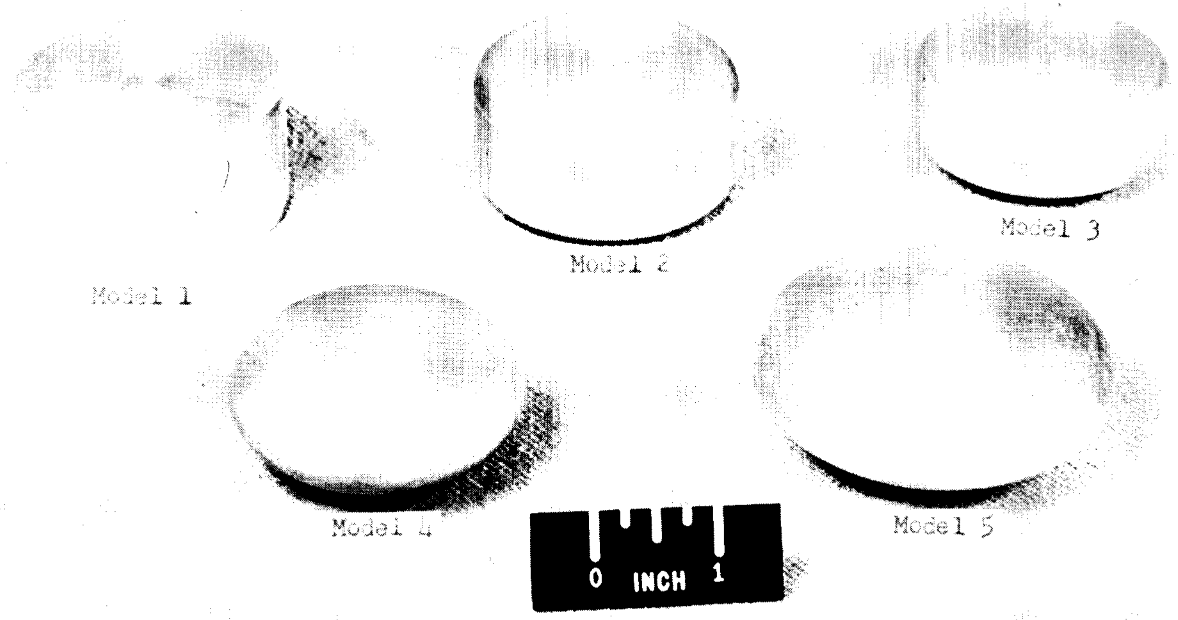

Figure 2.- Photograph of models tested. L-59-3492.1

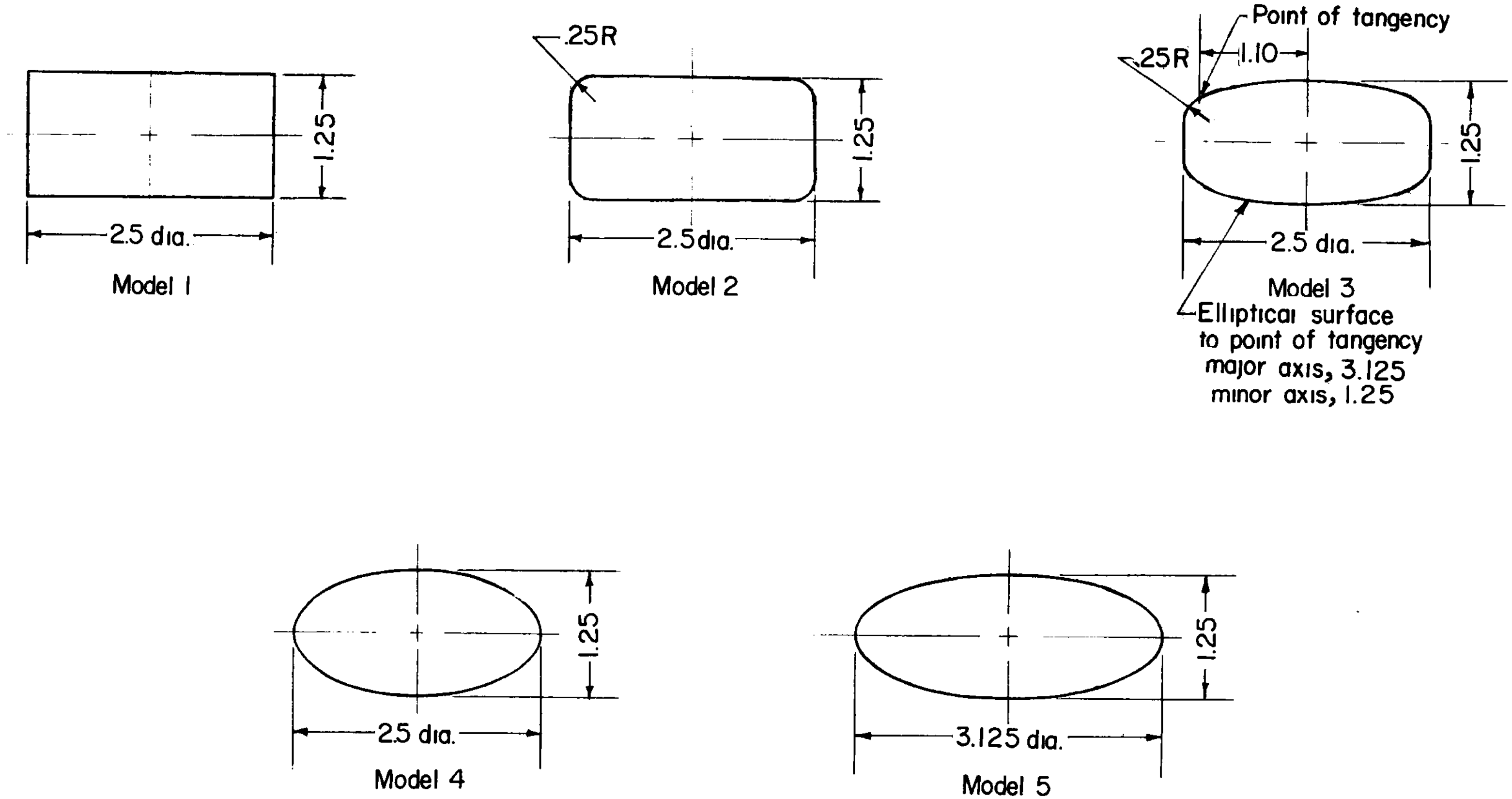

Figure 3.- Geometric characteristics of the root sections of the models. Root section is revolved about the vertical axis to form models. All dimensions are in inches.

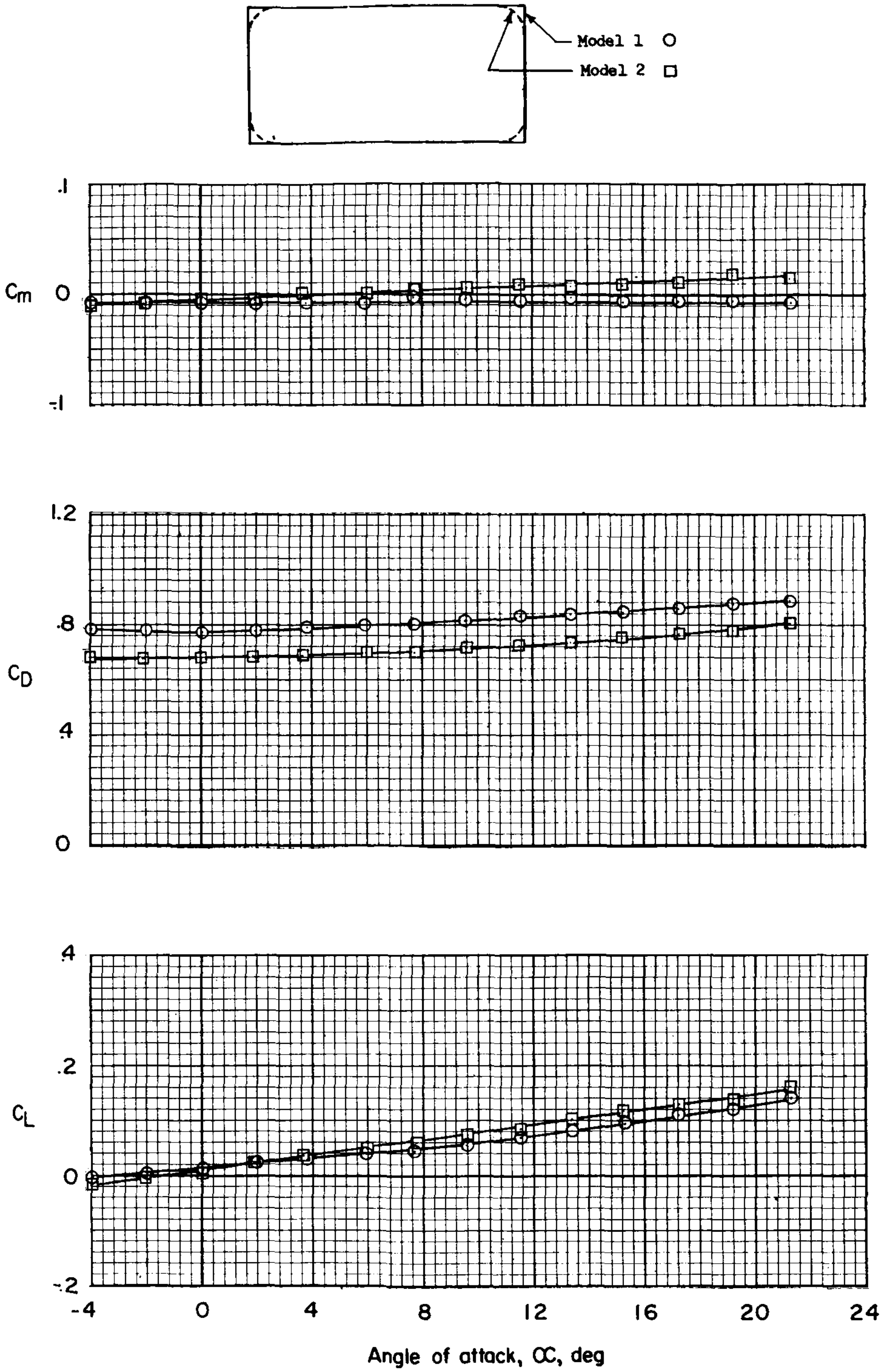

Figure 4.- Aerodynamic characteristics of models 1 and 2.

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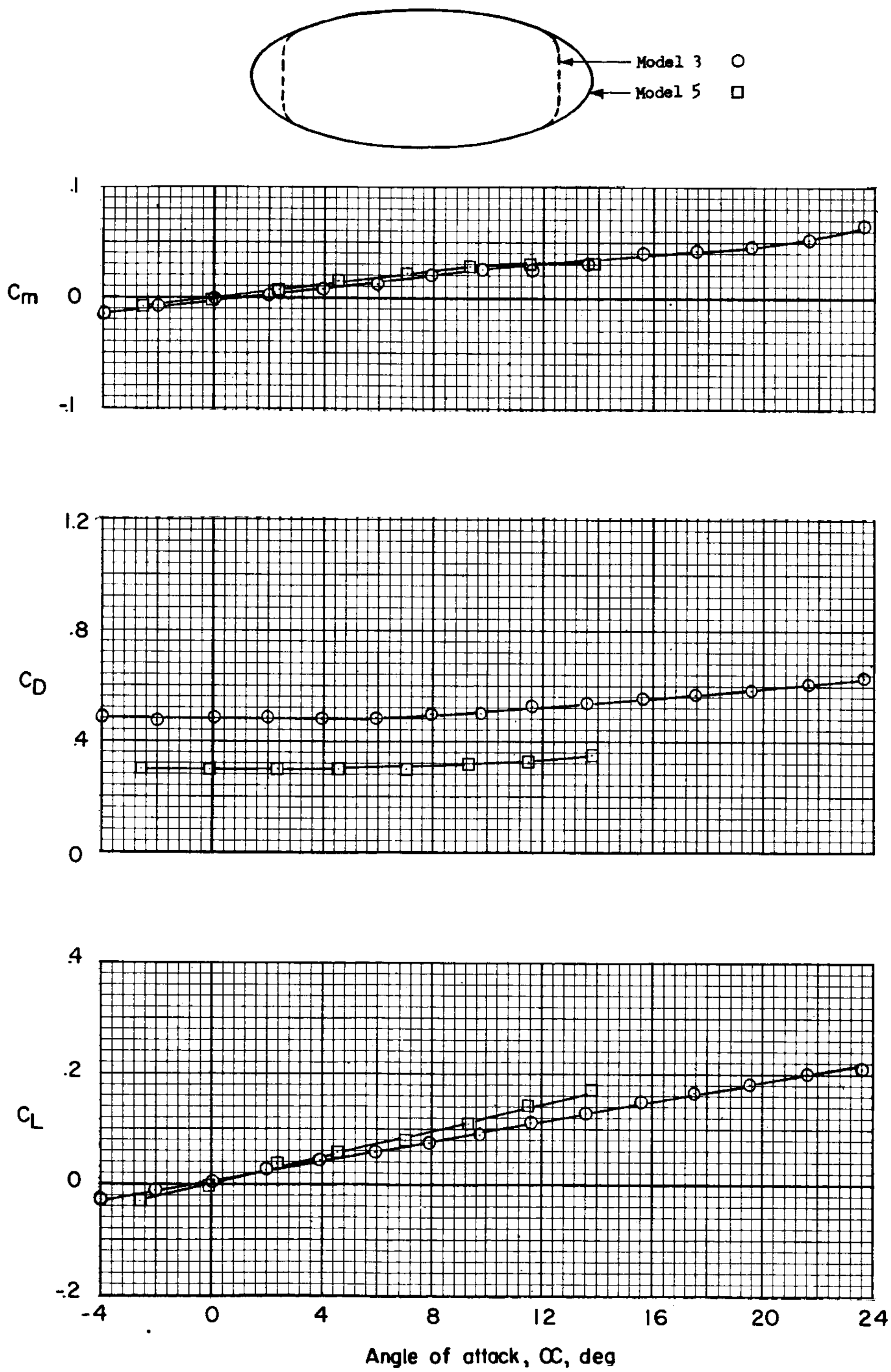

Figure 5.- Aerodynamic characteristics of models 3 and 5.

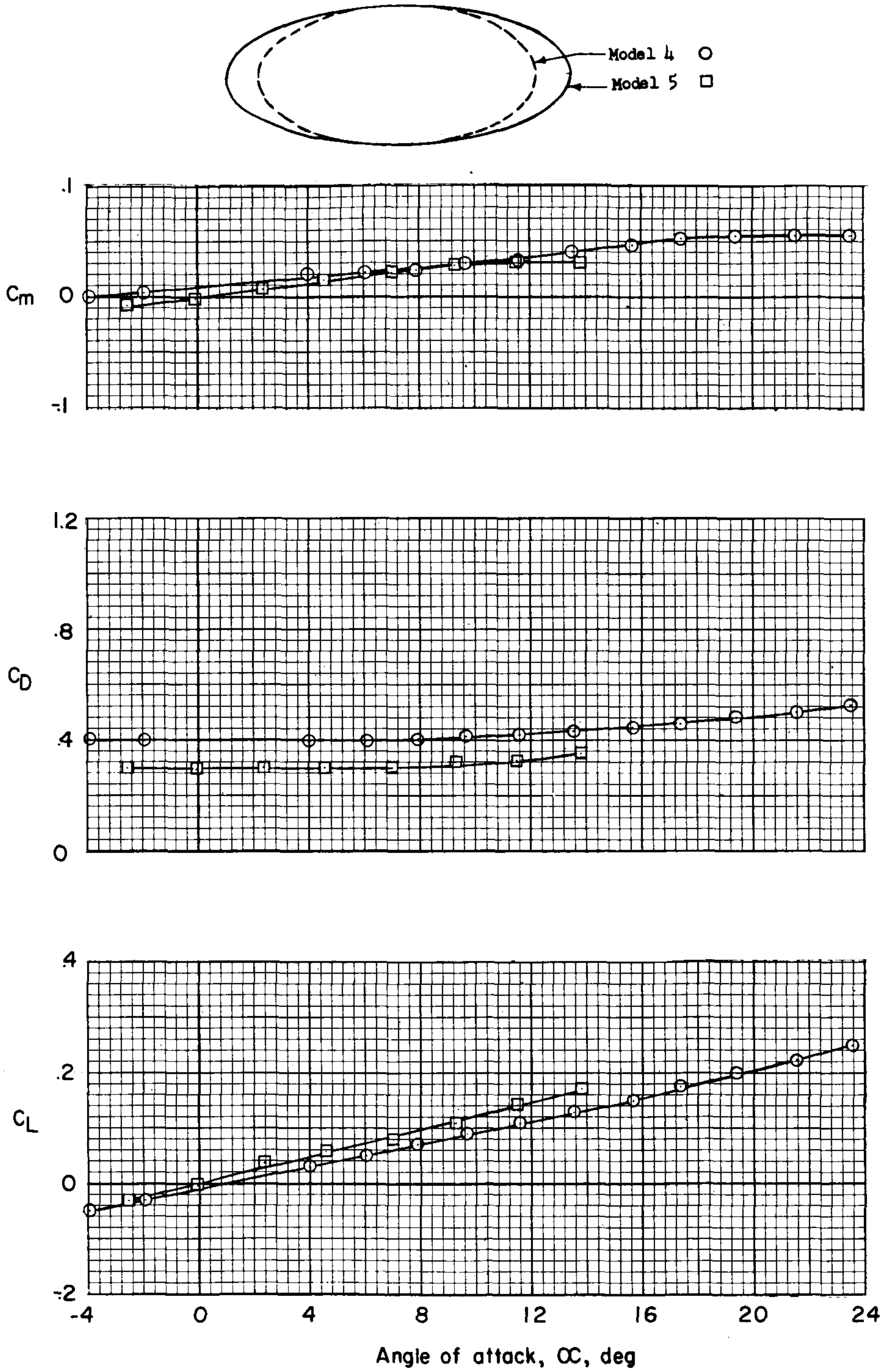

Figure 6.- Aerodynamic characterisitcs of models 4 and 5.

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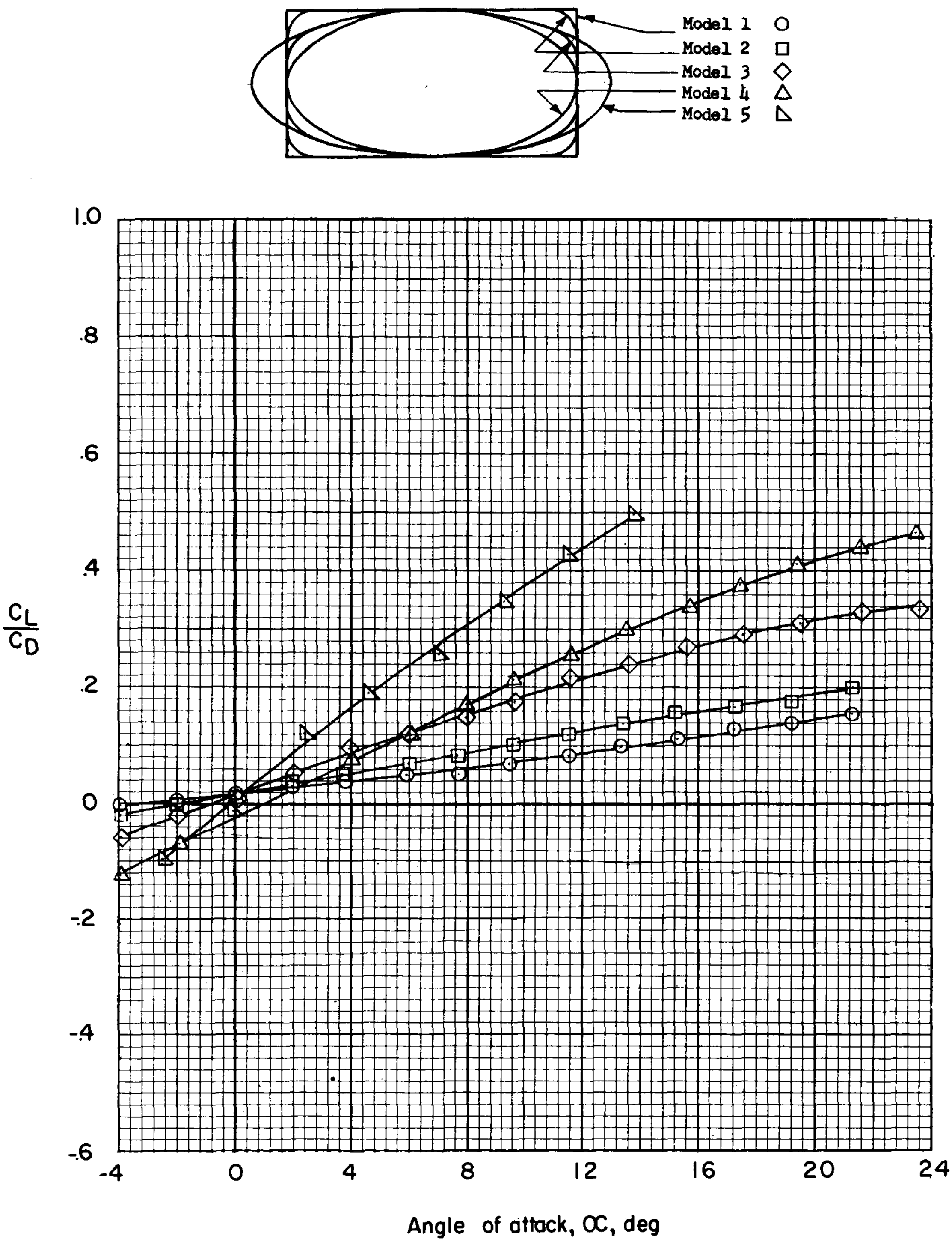

Figure 7.- Comparison of C_L/C_D for the models tested.